

Latest improvements in CODE's IGS MGEX solution

L. Prange, R. Dach, G. Beutler, D. Sidorov, A.
Villiger, S. Schaer, A. Jäggi

Astronomical Institute, University of Bern, Switzerland

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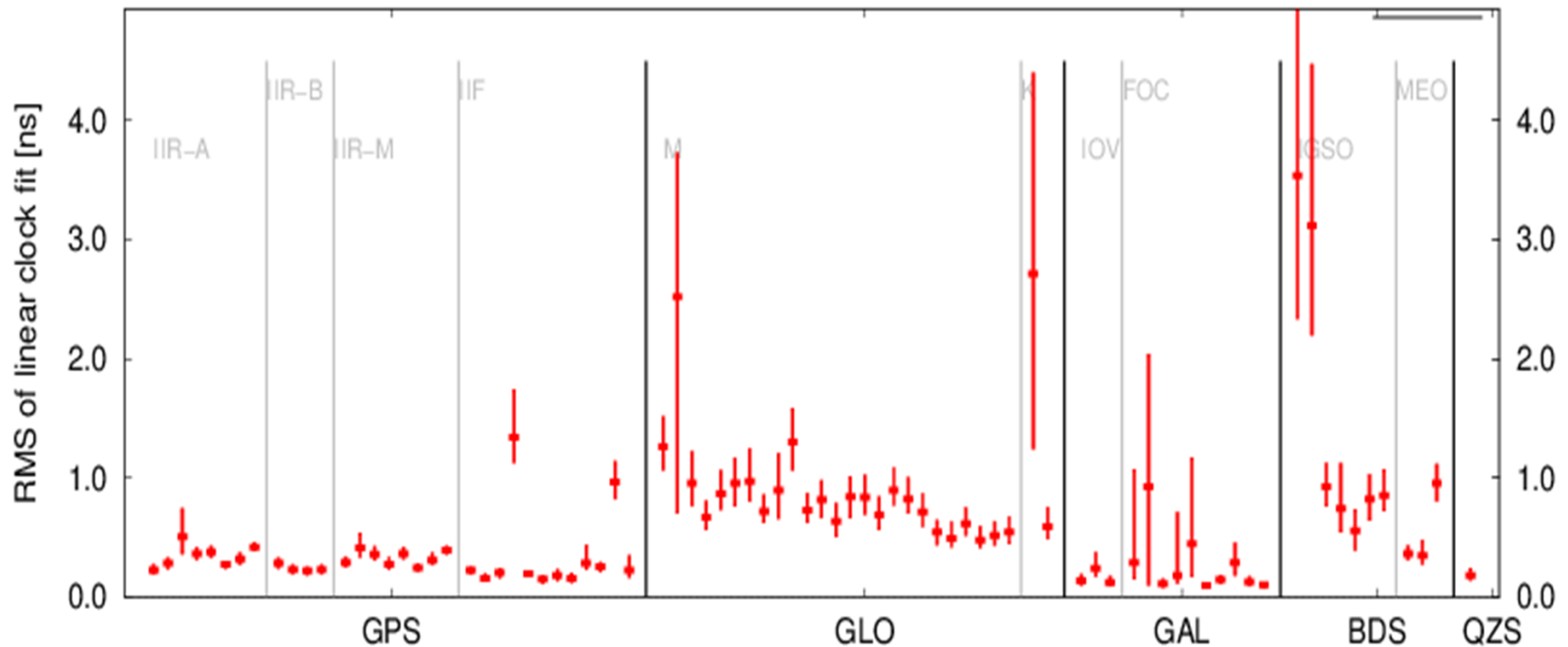
- Current status of the CODE MGEX solution
- Planned model changes
- Importance of satellite meta data
- Empirical SRP model for ON
- Summary and outlook

Focus of MGEX-related activity since last IGS WS

- Survey of preliminary state:
 - Publication in JoG (doi 10.1007/s00190-016-0968-8)
- Operations and related tasks:
 - Adaptation to long RINEX3 file names
 - Switch to default antenna model (Steigenberger et al., 2016)
 - Switch to IGS14
- Upgrade of operational status:
 - Full integration into CODE IGS routine (software, configuration, merge of data bases)
 - Reaction to MGEX status change at IGS WS 2016
 - Better coordination of parallel developments

COM clock validation 2016: daily linear fit

(Median and IQR; satellites in eclipse or normal mode are not considered)

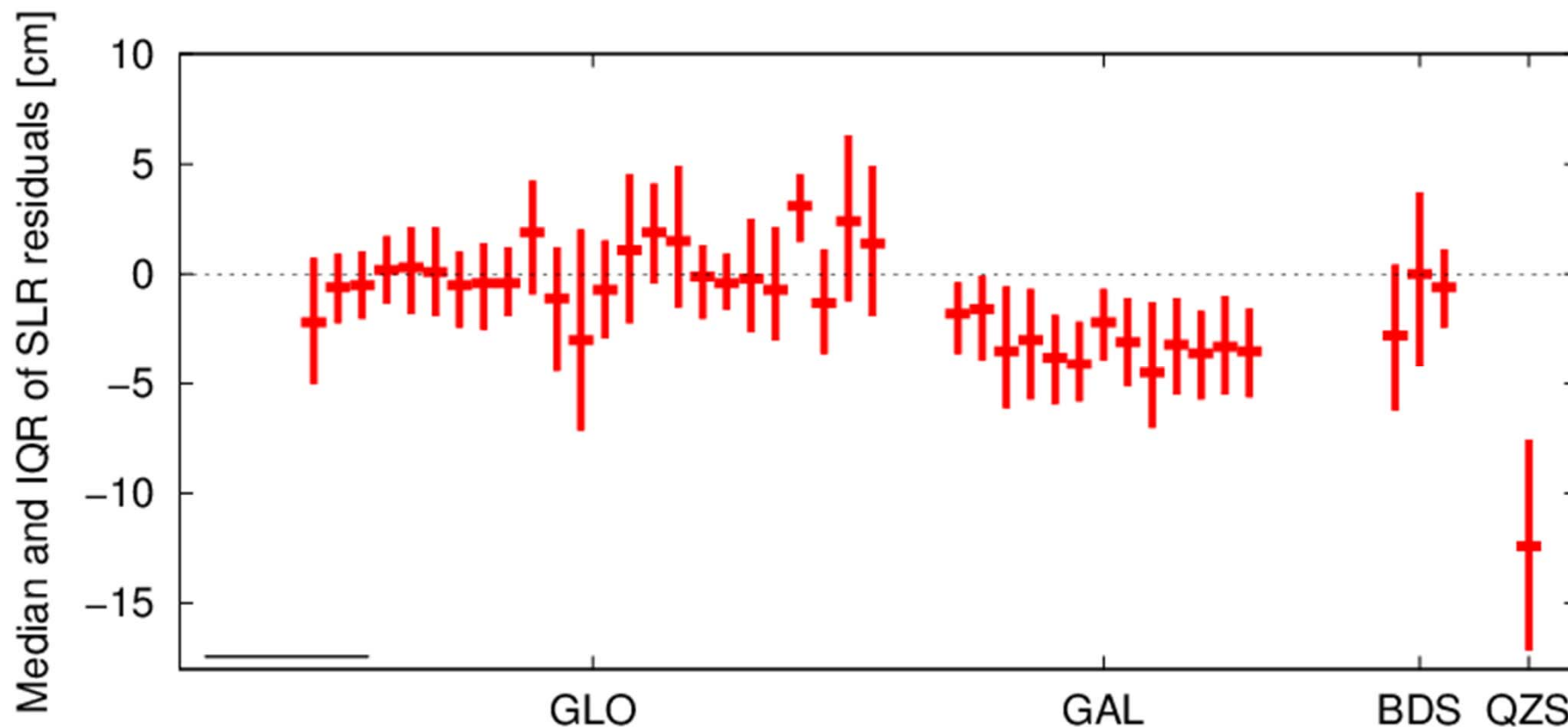


- ⇒ Galileo PHM, QZS-1, most GPS IIR and IIF: excellent clocks (even suited for orbit validation)
- ⇒ Some GPS IIF, GLONASS, Galileo RAFS: worse (RMS: 0.5 ns or bigger)
- ⇒ BeiDou: mixed performance

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COM orbit validation 2016: SLR residuals

(Median and IQR; satellites in eclipse or normal mode are not considered)



- ⇒ Significant SLR offsets for Galileo and QZSS due to orbit model deficiencies with impact on radial orbit component (respectively scale)
- ⇒ Model improvements are needed (e.g., ANTEX, albedo, antenna thrust)

Planned model changes

Improvements of orbit model planned in the near future:

- Galileo:**
- Activation of albedo and antenna thrust
 - Activation of IOV attitude model for all Galileo SC
 - Activation of pulses (every 12h in R,S,W)
 - IOV Antenna model (=> impact analysis: Villiger @plenary #6)
- QZSS:**
- Activation of albedo and antenna thrust ('guessed' box-wing model (own or external, e.g., Montenbruck et al. (2017)))
 - Later: Activation of ON attitude and suited SRP model
- BDS:**
- Later: Activation of ON attitude and suited SRP model

Importance of satellite meta data

- Missing satellite meta data is a limiting factor for accuracy of estimated orbits and clocks



- ⇒ Publication of Galileo IOV satellite meta data by the GSA in Dec. 2016 is a step towards the right direction
- ⇒ Missing/unsure information: we can try to make a 'good guess' (like previously done, e.g., for GLONASS antenna thrust; is this tolerable?)

Importance of satellite meta data

Available/assumed information:

- Galileo:**
- Disclosed IOV meta data (satellite mass, size, and surface properties) => sufficient for simple box-wing model
 - Disclosed IOV attitude model
 - Assuming same models for FOC might not be correct, but better than nothing
 - Measured antenna transmit power for IOV and FOC presented by Steigenberger et al. at EGU 2017

- QZSS:**
- Very coarse info about satellite size provided (e.g., on MGEX website); assumption on surface properties (e.g., similar to IOV) => rough guess on simple box-wing model
 - Wide range of possible SC masses is provided on the IGS-MGEX website (1800 - 4100 kg)
 - Transmission power provided by Kogure et al. in: Springer Handbook of Global Navigation Satellite Systems (2017)

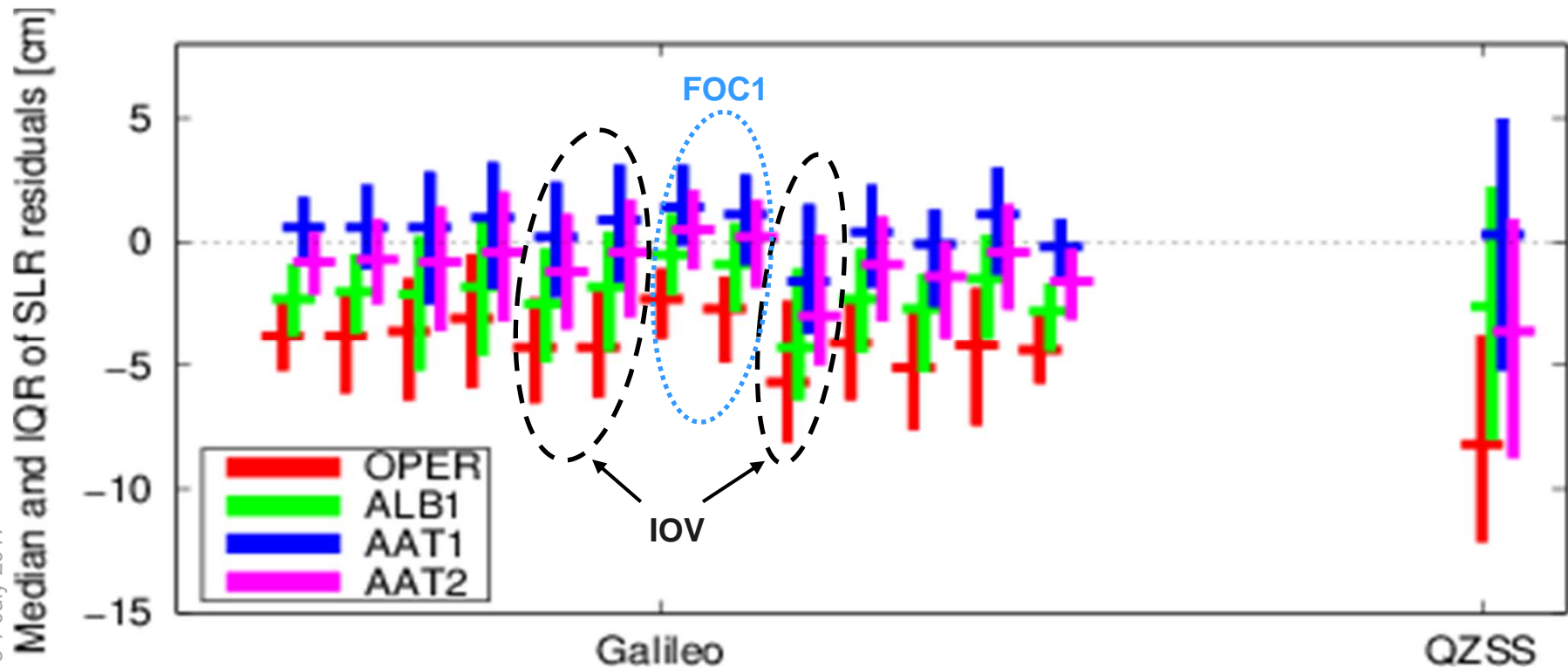
Importance of satellite meta data

Test	Galileo					QZSS		
Name	Albedo	Ant. Thr.	Attitude	Pulses	Median SLR [cm]	Albedo	Ant. Thr. (244 W)	Median SLR [cm]
OPER	–	–	–	–	–3.8	–	–	–7.8
ALB1	x	–	–	–	–2.0	m=1800 kg	–	–2.6
AAT1	x	260 W	–	–	+0.6	m=1800 kg	m=1800 kg	+0.3
AAT2	x	130 W	–	–	–0.7	m=3600 kg	m=3600 kg	–3.7
EAT	x	200 W	x	–	0.0	m=1950 kg	m=1950 kg	–0.3
EATPA	x	200 W	x	R, S, W; 12h	+0.6	m=1950 kg	m=1950 kg	–0.3

Importance of satellite meta data

Test	Galileo					QZSS		
Name	Albedo	Ant. Thr.	Attitude	Pulses	Median SLR [cm]	Albedo	Ant. Thr. (244 W)	Median SLR [cm]
OPER	–	–	–	–	–3.8	–	–	–7.8
ALB1	x	–	Impact albedo: +1.8 cm			m=1800 kg	–	–2.6
AAT1	x	260 W	–	–	+0.6	m=	m=	+0.3
AAT2	x	130 W	Impact antenna thrust: 1 cm/100 W			Impact SC mass: 2.2 cm/1000 kg		
					0.7	3600 kg	3600 kg	–3.7
EAT	x	200 W	x	–	0.0	m=1950 kg	m=1950 kg	–0.3
EATPA	x	200 W	x	R, S, W; 12h	+0.6	m=1950 kg	m=1950 kg	–0.3

Importance of satellite meta data

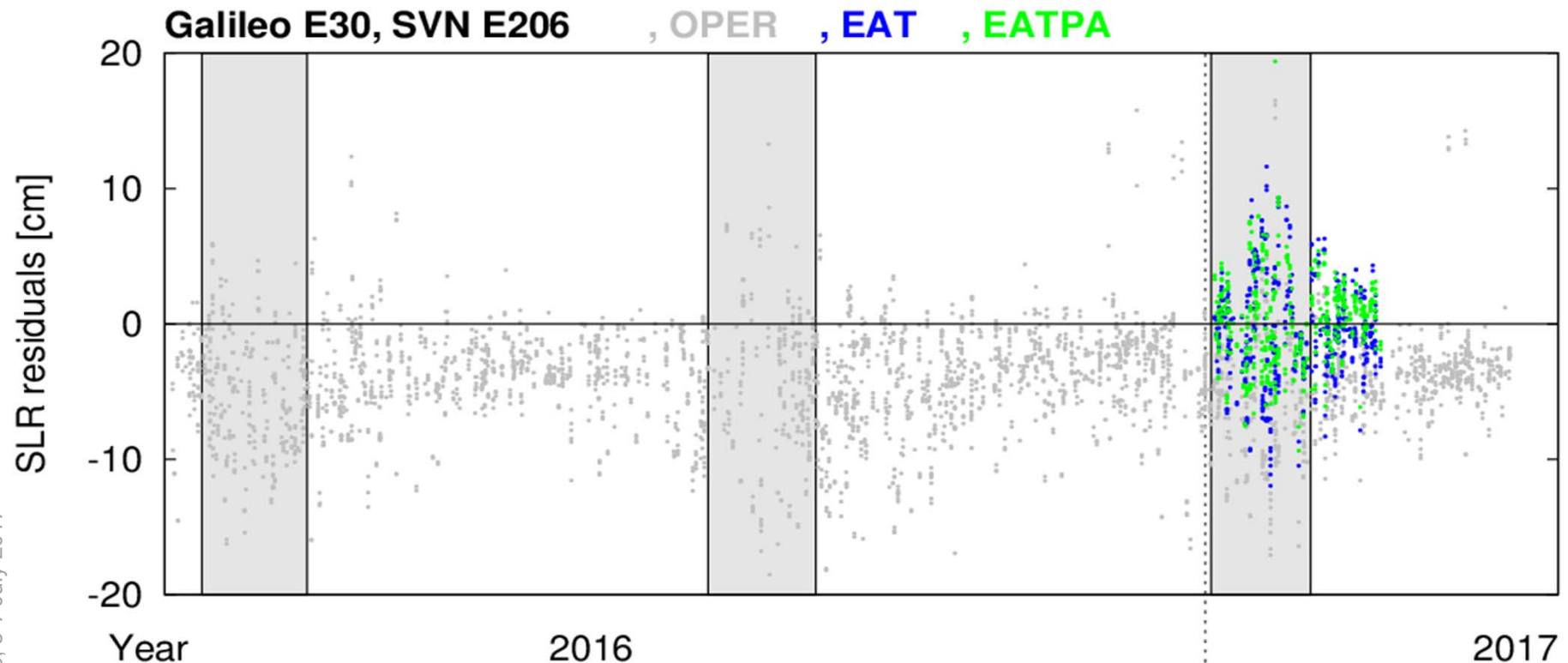


⇒ Consideration of albedo and antenna thrust reduces SLR offset

⇒ Uncertainties remain:

- Satellite macro model is rough (IOV) or guessed (FOC, QZSS)
- True satellite mass and CoM unknown (QZSS)
- Uncertainties w.r.t. transmit power
- Antenna calibration also impacts orbit scale

Expected impact of model changes

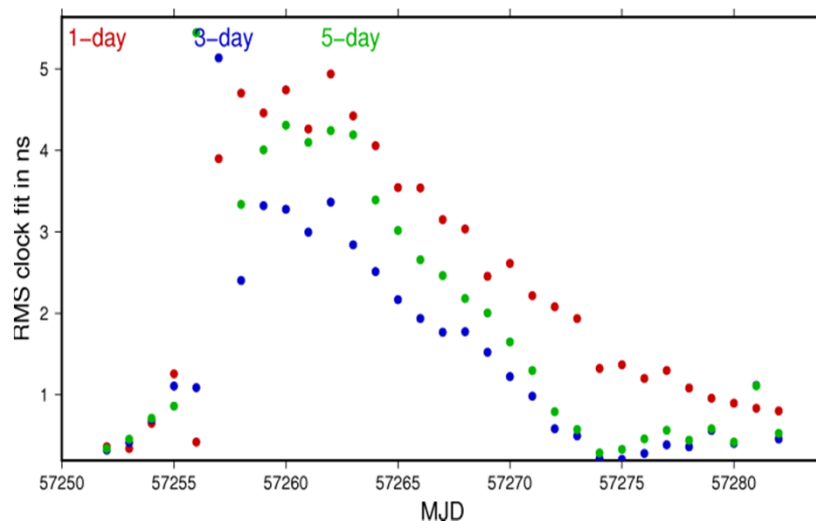


- ⇒ IOV attitude model (OPER vs. EAT): minimal impact
- ⇒ Pulses in R, S, W (EATPA): IQR drops 4.8 → 3.8 cm
(expected future configuration)
- ⇒ Orbit errors remain increased during eclipses (why?)

Orbit normal mode (ON)

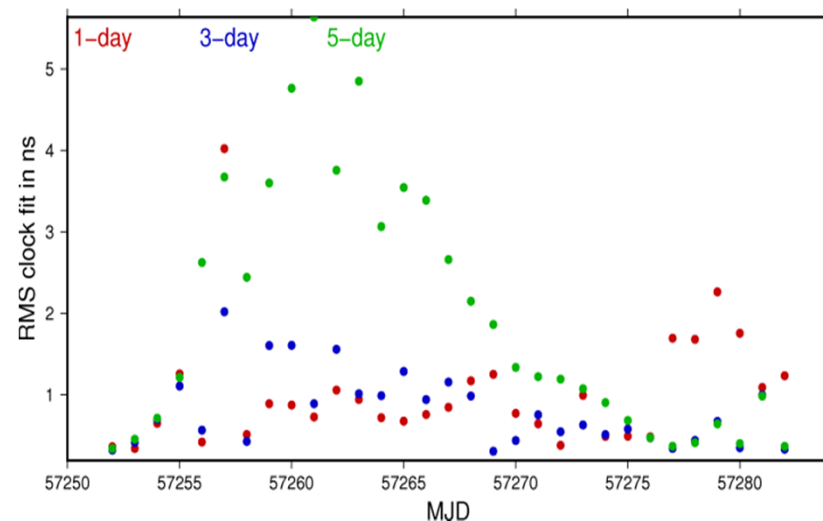
- Tests with QZS-1 and BDS POD
- Simulating and testing empirical SRP models using different decompositions and parameterizations (ECOM-N v...)

QZS-1 with ECOM2



Classical ECOM SRP models are not suited for ON

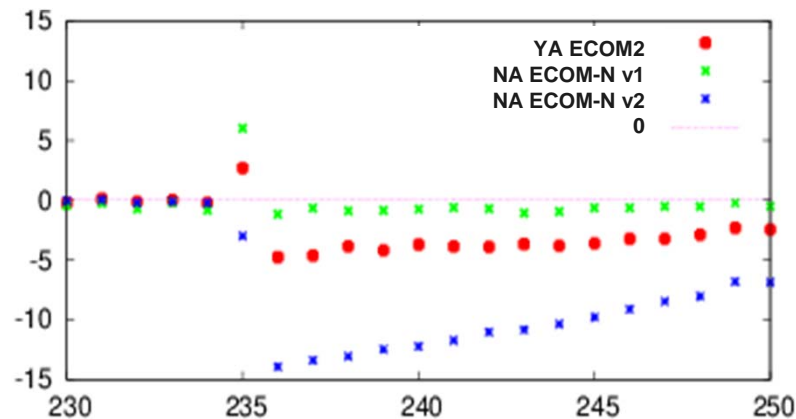
QZS-1 with ECOM-N v2



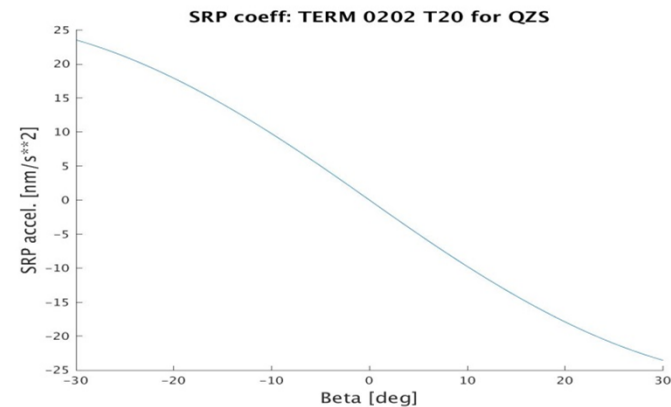
New SRP models: improvement for shorter arcs

Orbit normal mode (ON)

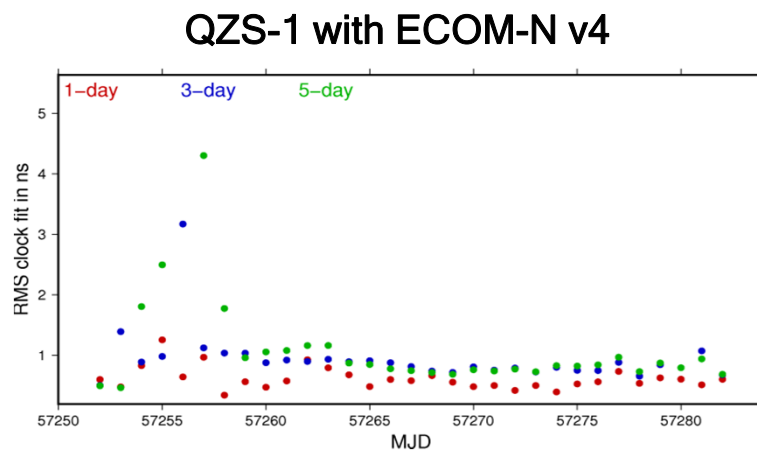
- Size of some new SRP parameters is a function of the Beta angle



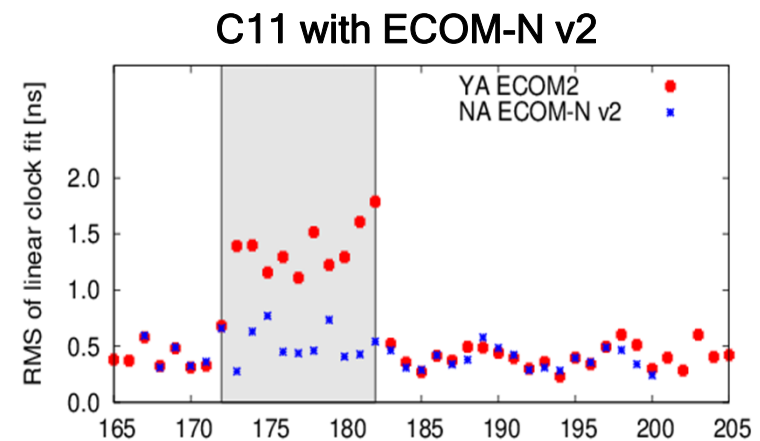
Estimated SRP coefficient of QZS-1



Simulated SRP coefficient of QZS-1



- QZS-1: consideration of Beta: improvement also for long arcs



- BDS: simple (no Beta-dependency) SRP model sufficient

COM to-do list

- ☒ Implementation of Galileo, QZSS, BeiDou (except GEOs)
- ☒ Use of RINEX3 files from IGS and EPN - now also with long file names; selection of observation types
- ☒ Improved SRP model for yaw-steering attitude (ECOM2, Arnold et al., 2015)
- ☒ Proper handling of observation biases; BIAS-SINEX
- ☐ Attitude laws for GPS, GLONASS, Galileo eclipses
- ☒ Tuning of ambiguity resolution for Galileo, BeiDou, QZSS
- ☐ Albedo radiation modelling for Galileo, QZSS, BeiDou
- ☐ Antenna thrust for (GLONASS), Galileo, QZSS, BeiDou
- ☐ Normal attitude and related SRP models for QZSS and BeiDou
- ☐ ANTEX (PCO+PCV) for Galileo, QZSS, BeiDou

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- ✓ P See clock- and bias-related presentations by Schaer (plenary #3) and Villiger (plenary #6)
- ... Attitude laws for GPS, GLONASS, Galileo eclipses
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- ... Antenna thrust for (GLONASS), Galileo, QZSS, BeiDou
- ... Normal attitude and related SRP models for QZSS and BeiDou
- ... A See ANTEX-related presentation by Villiger (plenary #3)

Thank you
for
your attention!